Giving Up Darwin - Claremont Review of Books

by David Gelernter

Darwinian evolution is a brilliant and beautiful scientific theory. Once it was a daring guess. Today it is basic to the credo that defines the modern worldview. Accepting the theory as settled truth—no more subject to debate than the earth being round or the sky blue or force being mass times acceleration—certifies that you are devoutly orthodox in your scientific views; which in turn is an essential first step towards being taken seriously in any part of modern intellectual life. But what if Darwin was wrong?

Like so many others, I grew up with Darwin's theory, and had always believed it was true. I had heard doubts over the years from well-informed, sometimes brilliant people, but I had my hands full cultivating my garden, and it was easier to let biology take care of itself. But in recent years, reading and discussion have shut that road down for good.

This is sad. It is no victory of any sort for religion. It *is* a defeat for human ingenuity. It means one less beautiful idea in our world, and one more hugely difficult and important problem back on mankind's to-do list. But we each need to make our peace with the facts, and not try to make life on earth simpler than it really is.

Charles Darwin explained monumental change by making one basic assumption—all life-forms descend from a common ancestor—and adding two simple processes anyone can understand: random, heritable variation and natural selection. Out of these simple ingredients, conceived to be operating blindly over hundreds of millions of years, he conjured up change that *seems* like the deliberate unfolding of a grand plan, designed and carried out with superhuman genius. Could nature really have pulled out of its hat the invention of life, of increasingly sophisticated life-forms and, ultimately, the unique-in-the-cosmos (so far as we know) human mind—given no strategy but trial and error? The mindless accumulation of small changes? It is an astounding idea. Yet Darwin's brilliant and lovely theory explains how it *could* have happened.

Its beauty is important. Beauty is often a telltale sign of truth. Beauty is our guide

to the intellectual universe—walking beside us through the uncharted wilderness, pointing us in the right direction, keeping us on track—most of the time.

Demolishing a Worldview

There's no reason to doubt that Darwin successfully explained the small adjustments by which an organism adapts to local circumstances: changes to fur density or wing style or beak shape. Yet there are many reasons to doubt whether he can answer the hard questions and explain the big picture—not the fine-tuning of existing species but the emergence of new ones. The origin of species is exactly what Darwin *cannot* explain.

Stephen Meyer's thoughtful and meticulous *Darwin's Doubt* (2013) convinced me that Darwin has failed. He cannot answer the *big* question. Two other books are also essential: *The Deniable Darwin and Other Essays* (2009), by David Berlinski, and *Debating Darwin's Doubt* (2015), an anthology edited by David Klinghoffer, which collects some of the arguments Meyer's book stirred up. These three form a fateful battle group that most people would rather ignore. Bringing to bear the work of many dozen scientists over many decades, Meyer, who after a stint as a geophysicist in Dallas earned a Ph.D. in History and Philosophy of Science from Cambridge and now directs the Discovery Institute's Center for Science and Culture, disassembles the theory of evolution piece by piece. *Darwin's Doubt* is one of the most important books in a generation. Few open-minded people will finish it with their faith in Darwin intact.

Meyer doesn't only demolish Darwin; he defends a replacement theory, intelligent design (I.D.). Although I can't accept intelligent design as Meyer presents it, he does show that it is a plain case of the emperor's new clothes: it says aloud what anyone who ponders biology *must* think, at some point, while sifting possible answers to hard questions. Intelligent design as Meyer explains it never uses religious arguments, draws religious conclusions, or refers to religion in any way. It does underline an obvious but important truth: Darwin's mission was exactly to explain the flagrant *appearance* of design in nature.

The religion is all on the other side. Meyer and other proponents of I.D. are the dispassionate intellectuals making orderly scientific arguments. Some I.D.-haters have shown themselves willing to use any argument—fair or not, true or not, ad hominem or not—to keep this dangerous idea locked in a box forever. They remind us of the extent to which Darwinism is no longer just a scientific theory but the basis of a worldview, and an emergency replacement religion for the many

troubled souls who need one.

As for Biblical religion, it forces its way into the discussion although Meyer didn't invite it, and neither did Darwin. Some have always been bothered by the harm Darwin is said to have done religion. His theory has been thought by some naïfs (fundamentalists as well as intellectuals) to have shown or alleged that the Bible is wrong, and Judeo-Christian religion bunk. But this view assumes a childishly primitive reading of Scripture. Anyone can see that there are two different creation stories in Genesis, one based on seven days, the other on the Garden of Eden. When the Bible gives us two different versions of one story, it stands to reason that the facts on which they disagree are without basic religious significance. The facts on which they *agree* are the ones that matter: God created the universe, and put man there for a reason. Darwin has nothing to say on these or any other key religious issues.

Fundamentalists and intellectuals might go on arguing these things forever. But normal people will want to come to grips with Meyer and the downfall of a beautiful idea. I will mention several of his arguments, one of them in (just a *bit* of) detail. This is one of the most important intellectual issues of modern times, and every thinking person has the right and duty to judge for himself.

Looking for Evidence

Darwin himself had reservations about his theory, shared by some of the most important biologists of his time. And the problems that worried him have only grown more substantial over the decades. In the famous "Cambrian explosion" of around half a billion years ago, a striking variety of new organisms—including the first-ever animals—pop up suddenly in the fossil record over a mere 70-odd million years. This great outburst followed many hundreds of millions of years of slow growth and scanty fossils, mainly of single-celled organisms, dating back to the origins of life roughly three and half billion years ago.

Darwin's theory predicts that new life forms evolve gradually from old ones in a constantly branching, spreading tree of life. Those brave new Cambrian creatures must therefore have had Precambrian predecessors, similar but not quite as fancy and sophisticated. They could not have all blown out suddenly, like a bunch of geysers. Each must have had a closely related predecessor, which must have had its own predecessors: Darwinian evolution is gradual, step-by-step. All those predecessors must have come together, further back, into a series of branches leading down to the (long ago) trunk.

But those predecessors of the Cambrian creatures are missing. Darwin himself was disturbed by their absence from the fossil record. He believed they would turn up eventually. Some of his contemporaries (such as the eminent Harvard biologist Louis Agassiz) held that the fossil record was clear enough already, and showed that Darwin's theory was wrong. Perhaps only a few sites had been searched for fossils, but they had been searched straight down. The Cambrian explosion had been unearthed, and beneath those Cambrian creatures their Precambrian predecessors should have been waiting—and weren't. In fact, the fossil record as a whole lacked the upward-branching structure Darwin predicted.

The trunk was supposed to branch into many different species, each species giving rise to many genera, and towards the top of the tree you would find so much diversity that you could distinguish separate phyla—the large divisions (sponges, mosses, mollusks, chordates, and so on) that comprise the kingdoms of animals, plants, and several others—take your pick. But, as Berlinski points out, the fossil record shows the opposite: "representatives of separate phyla appearing first followed by lower-level diversification on those basic themes." In general, "most species enter the evolutionary order fully formed and then depart unchanged." The incremental development of new species is largely not there. Those missing pre-Cambrian organisms have still not turned up. (Although fossils are subject to interpretation, and some biologists place pre-Cambrian life-forms closer than others to the new-fangled Cambrian creatures.)

Some researchers have guessed that those missing Precambrian precursors were too small or too soft-bodied to have made good fossils. Meyer notes that fossil traces of ancient bacteria and single-celled algae have been discovered: smallness *per se* doesn't mean that an organism can't leave fossil traces—although the existence of fossils depends on the surroundings in which the organism lived, and the history of the relevant rock during the ages since it died. The story is similar for soft-bodied organisms. Hard-bodied forms are more likely to be fossilized than soft-bodied ones, but many fossils of soft-bodied organisms and body parts do exist. Precambrian fossil deposits have been discovered in which tiny, soft-bodied embryo sponges are preserved—but no predecessors to the celebrity organisms of the Cambrian explosion.

This sort of negative evidence can't ever be conclusive. But the ever-expanding fossil archives don't look good for Darwin, who made clear and concrete predictions that have (so far) been falsified—according to many reputable paleontologists, anyway. When does the clock run out on those predictions? Never. But any thoughtful person must ask himself whether scientists today are looking

for evidence that bears on Darwin, or looking to explain away evidence that contradicts him. There are some of each. Scientists are only human, and their thinking (like everyone else's) is colored by emotion.

The Advent of Molecular Biology

Darwin's main problem, however, is molecular biology. There was no such thing in his own time. We now see from inside what he could only see from outside, as if he had developed a theory of mobile phone evolution without knowing that there were computers and software inside or what the digital revolution was all about. Under the circumstances, he did brilliantly.

Biology in his time was for naturalists, not laboratory scientists. Doctor Dolittle was a naturalist. (He is the hero of the wonderful children's books by Hugh Lofting, now unfortunately nearing extinction.) The doctor loved animals and understood them, and had a sharp eye for all of nature not too different from Wordsworth's or Goethe's. But the character of the field has changed, and it's not surprising that old theories don't necessarily still work.

Darwin's theory is simple to grasp; its simplicity is the heart of its brilliance and power. We all know that variation occurs naturally among individuals of the same type—white or black sheep, dove-gray versus off-white or pale beige pigeons, boring and sullen undergraduates versus charming, lissome ones. We all know that many variations have no effect on a creature's prospects, but some do. A sheep born with extra-warm wool will presumably do better at surviving a rough Scottish winter than his normal-wooled friends. Such a sheep would be more likely than normal sheep to live long enough to mate, and pass on its superior trait to the next generation. Over millions of years, small good-for-survival variations accumulate, and eventually (says Darwin) you have a brand new species. The same mechanism naturally favors genes that are right for the local environment—warm wool in Scotland, light and comfortable wool for the tropics, other varieties for mountains and deserts. Thus one species (your standard sheep) might eventually become four specialized ones. And thus new species should develop from old in the upward-branching tree pattern Darwin described.

The advent of molecular biology made it possible to transform Darwinism into Neo-Darwinism. The new version explains (it doesn't merely cite) natural variation, as the consequence of random change or mutation to the genetic information within cells that deal with reproduction. Those cells can pass genetic change onward to the next generation, thus changing—potentially—the future of the species and not

just one individual's career.

The engine that powers Neo-Darwinian evolution is pure chance and lots of time. By filling in the details of cellular life, molecular biology makes it possible to estimate the power of that simple mechanism. But what does *generating new forms of life* entail? Many biologists agree that generating a *new shape of protein* is the essence of it. Only if Neo-Darwinian evolution is creative enough to do that is it capable of creating new life-forms and pushing evolution forward.

Proteins are the special ops forces (or maybe the Marines) of living cells, except that they are common instead of rare; they do all the heavy lifting, all the tricky and critical assignments, in a dazzling range of roles. Proteins called enzymes catalyze all sorts of reactions and drive cellular metabolism. Other proteins (such as collagen) give cells shape and structure, like tent poles but in far more shapes. Nerve function, muscle function, and photosynthesis are all driven by proteins. And in doing these jobs and many others, the actual, 3-D *shape* of the protein molecule is important.

So, is the simple neo-Darwinian mechanism up to this task? Are random mutation plus natural selection sufficient to create new protein shapes?

Mutations

How to make proteins is our first question. Proteins are chains: linear sequences of atom-groups, each bonded to the next. A protein molecule is based on a chain of amino acids; 150 elements is a "modest-sized" chain; the average is 250. Each link is chosen, ordinarily, from one of 20 amino acids. A chain of amino acids is a polypeptide—"peptide" being the type of chemical bond that joins one amino acid to the next. But this chain is only the starting point: chemical forces among the links make parts of the chain twist themselves into helices; others straighten out, and then, sometimes, jackknife repeatedly, like a carpenter's rule, into flat sheets. Then the whole assemblage folds itself up like a complex sheet of origami paper. And the actual 3-D *shape* of the resulting molecule is (as I have said) important.

Imagine a 150-element protein as a chain of 150 beads, each bead chosen from 20 varieties. But: only certain chains will work. Only certain bead combinations will form themselves into stable, useful, *well-shaped* proteins.

So how hard *is* it to build a useful, well-shaped protein? Can you throw a bunch of amino acids together and assume that you will get something good? Or must you choose each element of the chain with painstaking care? It happens to be *very*

hard to choose the right beads.

Inventing a new protein means inventing a new gene. (Enter, finally, genes, DNA etc., with suitable fanfare.) Genes spell out the links of a protein chain, amino acid by amino acid. Each gene is a segment of DNA, the world's most admired macromolecule. DNA, of course, is the famous double helix or spiral staircase, where each step is a pair of nucleotides. As you read the nucleotides along one edge of the staircase (sitting on one step and bumping your way downwards to the next and the next), each group of three nucleotides along the way specifies an amino acid. Each three-nucleotide group is a codon, and the correspondence between codons and amino acids is the genetic code. (The four nucleotides in DNA are abbreviated T, A, C and G, and you can look up the code in a high school textbook: TTA and TTC stand for phenylalanine, TCT for serine, and so on.)

Your task is to invent a new gene by *mutation*—by the accidental change of one codon to a different codon. You have two possible starting points for this attempt. You could mutate an existing gene, or mutate gibberish. You have a choice because DNA actually consists of valid genes separated by long sequences of nonsense. Most biologists think that the *nonsense sequences* are the main source of new genes. If you tinker with a valid gene, you will almost certainly make it worse—to the point where its protein misfires and endangers (or kills) its organism—long before you start making it better. The gibberish sequences, on the other hand, sit on the sidelines without making proteins, and you can mutate them, so far as we know, without endangering anything. The mutated sequence can then be passed on to the next generation, where it can be mutated again. Thus mutations can accumulate on the sidelines without affecting the organism. But if you mutate your way to an actual, valid new gene, your new gene can create a new protein and thereby, potentially, play a role in evolution.

Mutations *themselves* enter the picture when DNA splits in half down the center of the staircase, thereby allowing the enclosing cell to split in half, and the encompassing organism to grow. Each half-staircase summons a matching set of nucleotides from the surrounding chemical soup; two complete new DNA molecules emerge. A mistake in this elegant replication process—the wrong nucleotide answering the call, a nucleotide typo—yields a mutation, either to a valid blueprint or a stretch of gibberish.

Building a Better Protein

Now at last we are ready to take Darwin out for a test drive. Starting with 150

links of gibberish, what are the chances that we can mutate our way to a useful new shape of protein? We can ask basically the same question in a more manageable way: what are the chances that a random 150-link sequence will create such a protein? Nonsense sequences are essentially random. Mutations are random. Make random changes to a random sequence and you get another random sequence. So, close your eyes, make 150 random choices from your 20 bead boxes and string up your beads in the order in which you chose them. What are the odds that you will come up with a useful new protein?

It's easy to see that the total number of *possible* sequences is immense. It's easy to believe (although non-chemists must take their colleagues' word for it) that the subset of *useful* sequences—sequences that create real, usable proteins—is, in comparison, tiny. But we must know how immense and how tiny.

The total count of *possible* 150-link chains, where each link is chosen separately from 20 amino acids, is 20^{150}. In other words, *many*. 20^{150} roughly equals 10^{195}, and there are only 10^{80} atoms in the universe.

What proportion of these many polypeptides are useful proteins? Douglas Axe did a series of experiments to estimate how many 150-long chains are capable of stable folds—of reaching the final step in the protein-creation process (the folding) and of holding their shapes long enough to be useful. (Axe is a distinguished biologist with five-star breeding: he was a graduate student at Caltech, then joined the Centre for Protein Engineering at Cambridge. The biologists whose work Meyer discusses are mainly first-rate Establishment scientists.) He estimated that, of all 150-link amino acid sequences, 1 in 10^{74} will be capable of folding into a stable protein. To say that your chances are 1 in 10^{74} is no different, in practice, from saying that they are zero. It's not surprising that your chances of hitting a stable protein that performs some useful *function*, and might therefore play a part in evolution, are even smaller. Axe puts them at 1 in 10^{77}.

In other words: immense is so big, and tiny is so small, that neo-Darwinian evolution is—*so far*—a dead loss. Try to mutate your way from 150 links of gibberish to a working, useful protein and you are guaranteed to fail. Try it with ten mutations, a thousand, a million—you fail. The odds bury you. It can't be done.

A Bad Bet

But neo-Darwinianism understands that mutations are rare, and successful ones even scarcer. To balance that out, there are many organisms and a staggering

immensity of time. Your chances of winning might be infinitesimal. But if you play the game often enough, you win in the end, right? After all, it works for Powerball!

Do the numbers balance out? Is Neo-Darwinian evolution plausible after all? Axe reasoned as follows. Consider the whole history of living things—the entire group of every living organism ever. It is dominated numerically by bacteria. All other organisms, from tangerine trees to coral polyps, are only a footnote. Suppose, then, that every bacterium that has ever lived contributes one mutation before its demise to the history of life. This is a generous assumption; most bacteria pass on their genetic information unchanged, unmutated. Mutations are the exception. In any case, there have evidently been, in the whole history of life, around 10^{40} bacteria—yielding around 10^{40} mutations under Axe's assumptions. That is a very large number of chances at any game. But given that the odds each time are 1 to 10^{77} against, it is not large enough. The odds against blind Darwinian chance having turned up even one mutation with the potential to push evolution forward are $10^{40}x(1/10^{77})$—10^{40} tries, where your odds of success each time are 1 in 10^{77}—which equals 1 in 10^{37}. In practical terms, those odds are still zero. Zero odds of producing a single promising mutation in the whole history of life. Darwin loses.

His idea is still perfectly reasonable in the abstract. But concretely, he is overwhelmed by numbers he couldn't possibly have foreseen: the ridiculously large number of amino-acid chains relative to number of useful proteins. Those numbers transcend the details of any particular set of estimates. The obvious fact is that genes, in storing blueprints for the proteins that form the basis of cellular life, encode an awe-inspiring amount of information. You don't turn up a useful protein merely by doodling on the back of an envelope, any more than you write a Mozart aria by assembling three sheets of staff paper and scattering notes around. Profound biochemical knowledge is somehow, in some sense, captured in every description of a working protein. Where on earth did it all come from?

Neo-Darwinianism says that nature simply rolls the dice, and if something useful emerges, great. Otherwise, try again. But useful sequences are so gigantically rare that this answer simply won't work. Studies of the sort Meyer discusses show that Neo-Darwinism is the quintessence of a bad bet.

The Great Darwinian Paradox

There are many other problems besides proteins. One of the most basic, and the last I'll mention here, calls into question the whole idea of gene mutations driving macro-evolution—the emergence of new forms of organism, versus mere variation

on existing forms.

To help create a brand new form of organism, a mutation must affect a gene that does its job early and controls the expression of other genes that come into play later on as the organism grows. But mutations to these early-acting “strategic” genes, which create the big body-plan changes required by macro-evolution, seem to be invariably fatal. They kill off the organism long before it can reproduce. This is common sense. Severely deformed creatures don’t ever seem fated to lead the way to glorious new forms of life. Instead, they die young.

Evidently there are a total of *no* examples in the literature of mutations that affect early development and the body plan as a whole and are *not* fatal. The German geneticists Christiane Nüsslein-Volhard and Eric Wieschaus won the Nobel Prize in 1995 for the “Heidelberg screen,” an exhaustive investigation of every observable or inducible mutation of *Drosophila melanogaster* (the same patient, long-suffering fruit fly I meddled with relentlessly in an undergraduate genetics lab in the 1970s). “[W]e think we’ve hit all the genes required to specify the body plan of *Drosophila*,” said Wieschaus in answering a question after a talk. Not one, he continued, is “promising as raw materials for macroevolution”—because mutations in them all killed off the fly long before it could mate. If an exhaustive search rules out *every last plausible gene* as a candidate for large-scale Drosophila evolution, where does that leave Darwin? Wieschaus continues: “What *are*—or what *would be*—the right mutations for major evolutionary change? And we don’t know the answer to that.”

There is a general principle here, similar to the earlier principle that the number of useless polypeptides crushes the number of useful ones. The Georgia Tech geneticist John F. McDonald calls this one a “great Darwinian paradox.” Meyer explains: “genes that are obviously variable within natural populations seem to affect only minor aspects of form and function—while those genes that govern major changes, the very stuff of macroevolution, apparently do not vary or vary only to the detriment of the organism.” The philosopher of biology Paul Nelson summarizes the body-plan problem:

> Research on animal development and macroevolution over the last thirty years—research done from within the neo-Darwinian framework—has shown that the neo-Darwinian explanation for the origin of new body plans is overwhelmingly likely to be false—and for reasons that Darwin himself would have understood.

Darwin would easily have understood that minor mutations are common but can't create significant evolutionary change; major mutations are rare and fatal.

It can hardly be surprising that the revolution in biological knowledge over the last half-century should call for a new understanding of the origin of species.

Darwin's Limits

Intelligent Design, as Meyer describes it, is a simple and direct response to a specific event, the Cambrian explosion. The theory suggests that an intelligent cause intervened to create this extraordinary outburst. By "intelligent" Meyer understands "conscious"; the theory suggests nothing more about the designer. But where is the evidence? To Meyer and other proponents, that is like asking—after you have come across a tree that is split vertically down the center and half burnt up—"but where is the *evidence* of a lightning strike?" The exceptional intricacy of living things, and their elaborate mechanisms for fitting precisely into their natural surroundings, seemed to cry out for an intelligent designer long before molecular biology and biochemistry. Darwin's theory, after all, is an attempt to explain "design without a designer," according to evolutionary biologist Francisco Ayala. An intelligent designer might seem more necessary than ever now that we understand so much cellular biology, and the impossibly long odds facing any attempt to design proteins by chance, or assemble the regulatory mechanisms that control the life cycle of a cell.

Meyer doesn't reject Darwinian evolution. He only rejects it as a sufficient theory of life as we know it. He's made a painstaking investigation of Darwin's theory and has rejected it for many good reasons that he has carefully explained. He didn't rush to embrace intelligent design. Just the opposite. But the explosion of detailed, precise information that was necessary to build the brand-new Cambrian organisms, and the fact that the information was *encoded*, represented symbolically, in DNA nucleotides, suggests to Meyer that an intelligent designer must have been responsible. "Our uniform experience of cause and effect shows that intelligent design is the *only known cause* of the origin of large amounts of functionally specified digital information," he writes. ("Digital" is confusing here; it only means information represented by a sequence of symbols.)

Was the Cambrian Explosion unique in some absolute sense, or was it the extreme endpoint of a spectrum? After all, there were infusions of new genetic information before and after. Meyer himself writes that "the sudden appearance of the Cambrian animals was merely the most outstanding instance of a pattern of

discontinuity that extends throughout the geologic column."

It's not easy to decide whether something stands alone or at the far end of some spectrum. Consider Meyer's "functionally specified digital information." Information intended for one specific purpose and spelled out in a sequence of symbols is a rare bird in nature. It's an outlier in the world of intelligence, too. We nearly always communicate in symbols that are used for *many* purposes; it's hard for us to confine any symbol system to a single purpose. Even digits are used to represent numbers of many kinds, to express order as well as magnitude, as names (*2001: A Space Odyssey*) or parts of English phrases ("second rate"). A line of music can be heard in the head, hummed or sung, played on a zither or performed by a large orchestra. Or it can serve as a single graphic symbol meaning "music." But the genetic code is used to specify the structure of certain molecules *only* (albeit in a series of separate steps and information-transfers within the cell). Nature, for its part, encodes information in many ways: airborne scents are important to bees, butterflies, elephants seeking to mate, birds avoiding trouble, and untold other creatures. The scent is a symbol; it's not the *scent* that threatens the bird. Channels in sand dunes encode information about the passing breezes—and so on. There are endless examples—none approaching the sophistication and complexity of DNA coding.

If Meyer were invoking a single intervention by an intelligent designer at the invention of life, or of consciousness, or rationality, or self-aware consciousness, the idea might seem more natural. But then we still haven't explained the Cambrian explosion. An intelligent designer who interferes repeatedly, on the other hand, poses an even harder problem of explaining why he chose to act when he did. Such a cause would necessarily have some sense of the big picture of life on earth. What was his strategy? How did he manage to back himself into so many corners, wasting energy on so many doomed organisms? Granted, they might each have contributed genes to our common stockpile—but could hardly have done so in the most efficient way. What was his purpose? And why did he do such an awfully slipshod job? Why are we so disease prone, heartbreak prone, and so on? An intelligent designer makes perfect sense in the abstract. The real challenge is how to fit this designer into life as we know it. Intelligent design might well be the ultimate answer. But as a theory, it would seem to have a long way to go.

A Final Challenge

I might, myself, expect to find the answer in a phenomenon that acts as if it were a new and (thus far) unknown force or field associated with consciousness. I'd

expect complex biochemistry to be consistently biased in the direction that leads closer to consciousness, as gravitation biases motion towards massive objects. I have no evidence for this idea. It's just the way biology seems to work.

Although Stephen Meyer's book is a landmark in the intellectual history of Darwinism, the theory will be with us for a long time, exerting enormous cultural force. Darwin is no Newton. Newton's physics survived Einstein and will always survive, because it explains the cases that dominate all of space-time except for the extreme ends of the spectrum, at the very smallest and largest scales. It's just these most important cases, the ones we see all around us, that Darwin *cannot* explain. Yet his theory does explain cases of real significance. And Darwin's intellectual daring will always be inspiring. The man will always be admired.

He now poses a final challenge. Whether biology will rise to this last one as well as it did to the first, when his theory upset every apple cart, remains to be seen. How cleanly and quickly can the field get over Darwin, and move on?—with due allowance for every Darwinist's having to study all the evidence for himself? There is one of most important questions facing science in the 21st century.

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